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In re Patent Application of: **Joseph Nathan Mitchell et al.**

For: **THERMALLY ACTUATED SPECTROSCOPIC OPTICAL SWITCH**

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For: ***Thermally Actuated Spectroscopic Optical Switch***

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IN THE UNITED STATES PATENT & TRADEMARK OFFICE

TITLE

THERMALLY ACTUATED SPECTROSCOPIC OPTICAL SWITCH

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SwRI ID# 2816

FIELD

The present invention generally relates to the switching of light beams carried by different fiber optic cables to a single light beam receptor; more particularly, the present invention relates to an optical switch that is suitable for use in spectroscopic applications.

BACKGROUND

The use of optical methods for testing, measuring, and system operations has become increasingly important. Optical methods are especially important for use in monitoring system operations, particularly when the monitoring of system operations is conducted by means such as absorption, emission, reflectance, fluorescence, or Raman spectroscopy. All of these monitoring methods require that a light beam be guided, usually by an optical fiber, to a detection device or a receptor, which, in many cases, is a spectrograph. In monitoring situations which include the simultaneous analysis of multiple samples or the analysis of points that are spatially separated, either multiple detectors, multiple receptors, or the imaging of multiple inputs on a single detector or receptor is required.

It has been found that prior art approaches for imaging multiple inputs on a single detection device or a single receptor are not always feasible. For example, if one wants to image a two-dimensional area of a sample, as is done in confocal Raman spectroscopy, typically there is only sufficient imaging space available on the detection

device for one image. Hence, in order to obtain two-dimensional images from several samples, the light input source must be switched to enable use of a single spectrograph.

The potential applications for a spectroscopic grade fiber optical switch are many. For example, a single spectrograph could be shared among several investigations, reducing the expense associated with duplicating equipment, and conserving precious rack space.

In yet another potential application, a spectroscopic grade fiber optical switch could be used on a planetary lander **100** (Figure 1) to switch input channels. For example, a single spectrograph could receive inputs from fiber optic probes on the robot arm, fiber optic probes in the bore of a drilled hole, fiber optic probes on lander legs, or fiber optic probes **102** harpooned away from the planetary lander as shown in Figure 1.

In yet still another potential application (e.g., Raman spectroscopy), the problem exists that inorganic minerals are better analyzed using an incident wavelength in the visible range (e.g., 532 nm), while organic materials are better analyzed in the near infrared wavelength range (e.g., 1064 nm). A fiber optic switch could be used to switch laser light beams to a single, dual wavelength, imaging spectrograph.

Prior art devices exist for routing optical signals, but these prior art devices have many limitations. One prior art method uses a mechanical fiber switch that relies on motors to physically align several optical fibers. These prior art active optical switching methods tend to be slow, bulky, and expensive. Additionally, these prior art active optical switching methods are not suitable for applications in space travel since the

moving parts may cold-weld together, thereby disabling the optical switching mechanism.

Another prior art active method for routing optical signals is electro-optical switching. The devices using electro-optical switching have no moving components and provide their switching action by the application of a voltage that produces a phase-shift in a waveguide to redirect the light beam. The electro-optical switching method is fast, but has a wavelength range which is limited to only a few nanometers.

Several prior art passive optical "switching" methods are available. One example of a prior art passive switching method is a polarizing splitter. Polarizing splitters can only redirect a light beam having a specific polarization. However, the use of polarizing splitters results in the loss of information that may be contained in the polarization state of the light. Additionally, using only polarized light results in a 50% loss in intensity.

Another prior art passive switch method is a fused splitter. Fused splitters can also be used to split or combine optical signals between multiple fibers. Specifically, fused splitters are constructed by fusing and tapering two optical fibers together. Fusing and tapering two optical fibers together provides a simple, rugged, and compact method of splitting and combining optical signals. Typical excess losses in fused splitters are low, while splitting ratios are accurate to within ±5 percent at the design wavelength. Fused splitters are bi-directional and offer low backreflection. However, fused splitters suffer from some disadvantages. Specifically, signal intensity in fused splitters is split

between the outputs. This splitting between the outputs results in high loss for larger port counts.

Still another type of prior art passive switching method is a multi-mode fused splitter. Multi-mode fused splitters have a somewhat limited spectral range and are mode dependent. Certain modes within one fiber in multi-mode fused splitters are transferred to the second fiber, while other modes are not. As a result, the splitting ratio in multi-mode fused splitters will depend on what modes are excited within the fiber. In comparison, single mode fused splitters only transmit one mode. Accordingly, single mode fused splitters do not suffer from mode dependency. However, single mode fused splitters are even more highly wavelength-dependent. A difference in wavelength of only 10 nm can cause a significant change in the splitting ratio.

Except for some mechanical active optical switching methods which use motors, no prior art switching technique can achieve the broad wavelength range and the low signal loss required for spectroscopic measurement (e.g., Raman spectroscopy applications.) However, optical switching methods that use motors or gears to mechanically align fibers are prone to problems in space (e.g., cold welding, stiction). Therefore, to achieve the full potential of distributed multi-spectral optical sensing, a small, inexpensive, broadband, reliable, fast, and low-loss optical switch is required.

Accordingly, there remains a need in the art for an optical switch suitable for use in fiber-optic spectroscopy which is small, inexpensive, reliable, has no moving parts (causing friction and possible cold-welding in space applications), and is able to cover a large wavelength range.

SUMMARY

The thermally actuated spectroscopic optical switch of the present invention is small, inexpensive, reliable, has no moving parts, and is able to cover a large range of wavelengths. The design of the thermally actuated spectroscopic optical switch of the present invention has a number of advantages over other types of switches. Being a MEMS-based (MicroElectroMechanical Systems) device, the disclosed thermally actuated spectroscopic optical switch benefits from all the advantages of small size and batch fabrication. The disclosed thermally actuated spectroscopic optical switch includes an array of optical fibers and an array of movable reflective surfaces which are actuated by applying energy to the thermal actuator on which the reflective surface is mounted. The actuators do not have any physical contact with the surface (substrate) near the reflector. This absence of physical contact with the reflector eliminates stiction, wear, and cold welding problems.

The amount of deflection in thermal actuators and hence, the position of the reflector can be fully controlled since the amount of deflection is proportional to the applied current. Thermally actuated spectroscopic optical switches built according to the present invention have actuation speeds of about 100 msec or less.

The present invention also includes a method of spectroscopic switching utilizing a micromachined actuator that can select an input probe or switch between different wavelength sources.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the structure and operation of the thermally activated spectroscopic optical switch of the present invention may be had by reference to the following detailed description when taken in conjunction with the accompanying drawings, wherein:

Figures 1 is a perspective view in a lander which includes a single spectrograph addressed by different input fibers;

Figures 2A and 2B are schematic diagrams illustrating the heating of a bimorph composite beam which causes one material to expand more than the other material, which results in the bending of the bimorph composite beam.

Figure 3 is a top plan view a spectrometer optical switch with five inputs and one output;

Figures 4A and 4B are a side elevational view and a top plan view, respectively, of a first embodiment (horizontal mirror) of a thermally actuated spectroscopic optical switch;

Figures 5A and 5B are a side elevational view and a top plan view, respectively, of a second embodiment (vertical mirror) of a thermally actuated spectroscopic optical switch;

Figure 6A is a perspective view of an alternative embodiment of a multi-layer balanced thermal actuator wherein an insulating material separates the upper and lower metal current path layers together with a vertical mirror mounted on the end of a cantilever beam;

Figure 6B is a perspective view of an alternative embodiment of a multi-layer balanced thermal actuator wherein the separation is by an air or vacuum gap together with a vertical mirror mounted on the end of the cantilever beam;

Figure 7 is a perspective view of a thermal actuator where the hot arm is positioned below the cold arm so that the thermal actuator will deflect upward when powered; and

Figure 8 is a cross-section of a cantilever thermal actuator.

DESCRIPTION OF THE EMBODIMENTS

<u>General</u>

As shown in Figures 3, 4A, 4B, 5A and 5B, the thermally actuated spectroscopic optical switch **10, 110**, **210** of the present invention is a MEMS-based device. A variety of schemes have been employed to actuate prior art MEMS-based devices. These prior art schemes include electrostatic, thermal (both bimorph and phase changing), electromagnetic, piezoelectric, and hydraulic actuators. Electrostatic devices are the most common MEMS devices, as they are versatile, simple to employ, energy efficient, and fully compatible with IC fabrication processes. However, electrostatic forces employed in electrostatic MEMS devices have a limited range and are non-linear. The displacement of an actuator in an electrostatic MEMS device can only be controlled over a small range, at which point the electrostatic MEMS device reaches an instability point known as the pull-in voltage. At the pull-in voltage, the actuator fully deflects to the opposite electrode. In space-based applications, deflecting to the opposite electrode is

not suitable since full deflection to the opposite electrode creates a physical contact point, thus triggering the potential for cold welding.

A variety of actuation methods have been utilized for prior art optical switching using micromachined devices. Comb-drives have been used to make a 2x2 switch with bare fibers. Scratch drives have been used for 2x2 switching. Scratch drives have also been used as actuators for an array of fold-up mirrors. Also proposed was an arrayed switch using torsion mirrors. A 1x8 switch has been made using micromotors.

Bimorph thermal actuators provide a more suitable actuation method since their deflection is a linear function of the change in material temperature. As shown in Figure 2A and Figure 2B, two materials having differing thermal expansion coefficients, such as aluminum **12** and silicon **14**, are bonded together to form bimorph thermal actuators. When heated, the aluminum **12** expands more than the silicon **14**. This difference in bending causes a composite beam made from these two materials to bend as shown in Figure 2B. The bending of the composite beam produces a deflection of the tip **16** of the beam.

Heating of the composite beam can be accomplished by using the conductive layers as resistive heaters. By applying a specific current to the heated part of the composite beam, a certain amount of deflection can be achieved.

When a composite beam is attached to a mirror, the bending of the composite beam can either angularly orient the mirror (in the horizontal design shown in Figures 4A and 4B) or move the mirrors up and down, in or out of the beampath (in the vertical design shown in Figures 3, 5A and 5B). These composite beam based devices

tend to require moderate power to operate. Specifically, the power requirements are on the order of one-hundred milliwatts. Thermal bimorph actuators have been used in a variety of experiments including scanning and micromanipulation.

Thermally actuated bimorphs have also been investigated for applications in fluidic valves and optical scanning. A thermally actuated cantilever beam has been used for gripping against a substrate, as a micro-tweezer. Optical scanning has been accomplished using a multilayer actuator with a reflective tip. In yet another application, a horizontal thermal cantilever has been made using a single material to drive a micromotor. However, thermally actuated cantilever beams have not found utilization in optical switches.

MEMS micromirrors have been utilized in a variety of applications, most notably in a commercial DLP projection system manufactured by Texas Instruments. The micromachined surfaces of MEMS mirrors exhibit little scattering since they are nearly atomically smooth. With a metallic coating, such as aluminum or gold, MEMS micromirrors can achieve a reflectivity of greater than 95% over a broad wavelength range.

Unlike the present invention, it has been found that all of the electrostatic MEMS devices make contact with the substrate as the actuator travels or slides along the surface of the substrate. It has also been found that such thermal actuators are either limited to a single direction of actuation, manipulate objects that slide along the surface of the substrate, or simply were not used for switching between optical fibers. Also, no

thermal actuators used with MEMS devices have been designed for use other than in room temperature environments.

Preferred Embodiment

As shown in Figure 3, Figure 4A and Figure 4B, the thermally actuated optical switch of the present invention may include an array of input fibers **20** and output fibers **30** together with an array of thermally actuated cantilever beams **40** which provide the switching action. Collimating lenses **50** are located at the end of the input fibers **20**, while collector lenses **60** are put in front of the output fibers **30**.

The thermally actuated spectroscopic optical switch **10** of the present invention comprises a single chip linear array of micro mirrors **25** positioned on a thermally actuated beam **40**. The thermally actuated beam **40**, shown in Figure 4A and Figure 4B, is a multi-layer cantilever structure with a mirror **25** positioned at the tip **16**. For example, the beam shown in Figure 4A and Figure 4B may be a silicon beam sandwiched between two materials having different coefficients of thermal expansion. On top of the two thermal expansion materials, a conductive layer may be coated.

In its simplest version, and as shown in Figure 8, the cantilever actuator has four layers. These four layers include a silicon wafer substrate **60**; a sacrificial oxide layer **62** which is removed to release the device; an insulating structural layer **64** with a first thermal expansion coefficient; and a conducting layer **66** with a second thermal expansion coefficient, such as a metal layer.

As shown in Figures 3, 4 and 4A, a chip **70** with an array of mirrors **25** will have multiple fibers placed around it. For example, as shown in Figure 3, one of

multiple input fibers **20** can be connected to a single output fiber **30**. Alternatively, multiple output fibers **20** can connect to a single input fiber **30**.

The thermal cantilever actuator **40** used in the present invention has a number of advantages over other types of actuators. Specifically, the thermal cantilever actuator **40** has no friction since it makes no physical contact with any surface. Likewise, the thermal cantilever actuator **40** will not be prone to any stiction or surface bonding that may occur in cold environments. The deflection of the thermal cantilever actuator **40** is fully controllable, unlike electrostatic actuators, since electrostatic actuators have only a small stable range before reaching their pull-in voltage. The thermal cantilever actuator **40** tends to be moderately fast operating, with an actuation speed on the order of 10-100 msec. In addition, a large deflection can be achieved. Specifically, it has been found that deflections on the order of 20% of the cantilever length can be obtained. Such large deflections correspond to an optical reflection angle of >20°.

The typical power consumption of a thermal cantilever actuator such as the one described herein is on the order of ten to one-hundred milliwatts. Finally, the thermal cantilever actuator **40** has no moving parts that can generate wear or breakage. Since the thermal cantilever actuator **40** can be formed using micromachining techniques, the use of a thermal cantilever actuator **40** obtains all the advantages of very compact size and the repeatability of fabrication needed to produce an operative array of movable mirrors for reflecting a beam of light.

In the horizontal mirror system **110** shown in Figures 4A and 4B, the light is incident at an angle to the chip face **70** and the mirrors **25** are raised to an angle that

intersects and deflects the light beam to the output fiber **30** shown in Figure 3. This embodiment allows the mirrors **25** to be fabricated substantially parallel to the plane of the wafer **70**. Fabricating the mirrors **25** in the plane of the wafer **70** eliminates any need for assembly since the resulting device is monolithic. Additionally, a very small actuator motion can achieve the desired deflection of the light beam without blocking other optical paths near the wafer.

<u>Alternate Embodiments</u>

The second embodiment **210** shown in Figures 5A and Figure 5B involves mirrors **225** that are mounted vertical to the plane of the wafer **70** and placed at a 45° angle to the incident optical beams **137**. In this embodiment both the incident **137** and reflected **139** light beams run parallel to the plane **170** of the wafer **135**. Running the incident **137** and reflected **139** light beams parallel to the plane of the wafer **70** simplifies the fiber placement since the fibers can be directly attached to the wafer **70** and aligned using integrated alignment grooves. This second embodiment **210** also allows for greater scalability since any input can be redirected to other outputs by adding additional rows of mirrors **225**.

The horizontal mirror embodiment shown in Figures 4A and Figure 4B is limited to multiple inputs and a single output, or multiple outputs and a single input, but the embodiment shown in Figures 5A and Figure 5B can be expanded to multiple inputs and multiple outputs, limited only by the wafer size.

Since the thermally actuated spectroscopic optical switch of the present invention must operate in a wide range of thermal environments, it has been designed so

as to minimize its response to changes in ambient temperature. Minimization of response to changes in ambient temperature can be accomplished for both embodiments **110, 210** by creating a thermally balanced actuator.

As shown in Figure 6A, a thermally balanced actuator **300** is a multi-layer structure that can be used with the middle layer **310** comprising an insulating dielectric structural material such as single crystal silicon, silicon dioxide, or silicon nitride located between (e.g. sandwiched between or attached to) two conducting layers **320** and **330**. Alternatively, as shown in Figure 6B, two individual bimorphs **340, 350** can be created, connected at the tip **316,** and separated by an air gap **360**. Each bimorph actuates in an opposite direction, such that both of the structures shown in Figures 6A and Figure 6B may be actuated in either direction. Being able to actuate in either direction results in faster actuation speeds since cooling is a slower process than heating. A thermally balanced actuator also reduces problems due to residual stresses in the film layers that produce the initial curvatures in released multi-layer structures.

The embodiment **400** shown in Figure 7 does not use a bimorph approach. Rather, this embodiment includes a narrow arm **420** and a wide arm **430**. Both arms **420, 430** can be made of the same material, arranged one above the other with a gap **460** between them and joined at the free end **416**. When current or electrical energy flows through the narrow arm **420**, the higher current density in the narrow arm **420** causes it to heat and expand more than in the wider "cold" arm **430**, with a resultant bending motion.

Additional optical elements must be added to the thermally actuated optical switch of the present invention to prevent large losses. The light beam output of a

fiber diverges rapidly, so, as shown in Figure 3, in the preferred embodiment, small microlenses **50, 60** have been placed in front of the fiber ends to collimate the light beam. Fiber coupled versions of both ball lenses and gradient index lenses are available for use that can produce collimated beams of only a few hundred microns diameter over a distance of several centimeters.

The behavior of a simple bimorph actuator as shown in Figures 6A and 6B can be explained fairly well in terms of composite beam theory. A current path is formed through the bimorph actuator such that a portion of the path will be highly resistive, creating localized heating. The increase in temperature causes the composite beam to expand. Since the two materials have different thermal expansion coefficients, they expand at different rates. This causes the composite beam to bend in the direction of the material with the lower coefficient of thermal expansion. For example, if an insulating layer were placed atop a metal layer, heating the composite beam would cause it to bend upward. The upward bending may then be used to deflect a mirror that is fabricated at the tip of the composite cantilever beam. The selective deflection of the mirror into a light beam causes reflection of the selected light beam.

Although the invention has been described with reference to specific embodiments, this description is not meant to be construed in a limited sense. Various modifications of the disclosed embodiments, as well as alternative embodiments of the inventions, will become apparent to persons skilled in the art upon the reference to the description of the invention. It is, therefore, contemplated that the appended claims will cover such modifications that fall within the scope of the invention.

CLAIMS

What is claimed is:

1. A system for directing a selected light beam to at least one light beam receptor, said system comprising:

an array of stationary optical fibers, each one of said stationary optical fibers constructed and arranged to conduct one of a plurality of light beams including the selected light beam; an array of movable reflective surfaces, each of said movable reflective surfaces being mounted on a thermal actuator;

whereby the application of electrical or heat energy to one of said thermal actuators will move said movable reflective surface mounted on said thermal actuator into the path of the selected light beam so that the selected light beam will be directed to the light beam receptor.

2. The system as defined in Claim 1, wherein the thermal actuator is frictionless.

3. The system as defined in Claim 1, wherein the thermal actuator has a cantilever mounting.

4. The system as defined in Claim 1, wherein the system is able to select among beams of light by changing the thermal actuator to which electrical or heat energy is directed.

5. The system as defined in Claim 1, wherein each one of the array of stationary optical fibers includes a collimating lens for directing the light beam toward said movable reflective surface.

6. The system as defined in Claim 1, wherein the selected light beam is directed to a collimating lens on the receptor.

7. The system as defined in Claim 1, wherein said thermal actuator is a silicon-based beam sandwiched between two layers of a material having a differing coefficient of thermal expansion.

8. The system as defined in Claim 1, wherein said thermal actuator is a silicon-based beam attached to a single layer of a material having a differing coefficient of thermal expansion.

9. The system as defined in Claim 1, wherein said thermal actuator includes a silicon wafer, a sacrificial layer, a material with a first coefficient of thermal expansion, and a material with a second coefficient of thermal expansion.

10. A method for directing a selected light beam emanating from one of a plurality of optical fibers to at least one light beam receptor, said method comprising the steps of:

(a) mounting the plurality of optical fibers in a fixed array;

(b) mounting a plurality of movable reflective surfaces on individual thermal actuators;

(c) energizing said thermal actuators to cause said movable reflective surface to intersect the selected light beam emanating from one of the plurality of optical fibers and direct said selected light beam to the light beam receptor.

11. The method as defined in Claim 10, wherein said thermal actuator is frictionless.

12. The method as defined in Claim 10, wherein said thermal actuator has a cantilever mounting.

13. The method as defined in Claim 10, wherein the thermal actuators are bimorph composite beams.

14. The method as defined in Claim 10, wherein said thermal actuators are silicon-based beams sandwiched between two layers of a material having a differing coefficient of thermal expansion.

15. The method as defined in Claim 10, wherein said thermal actuators are silicon-based beams attached to a single layer of a material having a differing coefficient of thermal expansion.

16. The method as defined in Claim 10, wherein said thermal actuators include a silicon wafer, a sacrificial layer, a material with a first coefficient of thermal expansion, and a material with a second coefficient of thermal expansion.

17. A thermally operated optical switch for use in directing a beam of light to at least one receptor, said thermally operated optical switch comprising:

a plurality of reflective surfaces arrayed in a first position substantially parallel to the beam of light; and

a plurality of energy sensitive flexible cantilever beams, each one of the plurality of flexible cantilever beams being affixed to a corresponding one of said plurality of reflective surfaces, wherein a selected energy sensitive flexible cantilever beam is constructed and arranged to bend a selected one of the plurality of reflective surfaces into a second position intersecting the light beam when connected to an energy source, whereby when said selected reflective surface is in said second position the light beam may be reflected to a receptor by the selected reflective surface which is caused to bend by the selected energy sensitive flexible cantilever beam.

18. The thermally operated optical switch as defined in Claim 17, wherein said selected energy sensitive flexible cantilever beam is frictionless.

19. The thermally operated optical switch as defined in Claim 17, wherein said thermally operated optical switch is able to select the beam of light from among a plurality of light beams by selecting the energy sensitive cantilever beam to which energy is directed.

20. The thermally operated optical switch as defined in Claim 17 wherein said energy sensitive flexible cantilever beam is a silicon-based beam sandwiched between two layers of a material having a differing coefficient of thermal expansion.

21. The thermally operated optical switch as defined in Claim 17 wherein said energy sensitive flexible cantilever beam is a silicon-based beam attached to a single layer of a material having a differing coefficient of thermal expansion.

22. The thermally operated optical switch as defined in Claim 17 wherein said energy sensitive flexible cantilever beam includes a silicon wafer, a sacrificial layer, a material with a first coefficient of thermal expansion, and a material with a second coefficient of thermal expansion.

23. The thermally operated switch as defined in Claim 17, wherein said energy sensitive flexible backing includes a pair of substantially parallel dielectric structural layers separated by an air layer, each of said substantially parallel dielectric structural layers including a conducting layer.

24. The thermally operated switch as defined in Claim 17 wherein said energy sensitive flexible beam includes a two substantially parallel cantilevered mounted arms, each of said two substantially parallel cantilever mounted arms having a different current density when connected to a source of electrical energy.

25. A thermally operated optical switch for use in directing at least one incident beam of light to at least one receptor, said thermally operated optical switch comprising:

a plurality of reflective surfaces arrayed in a first position substantially perpendicular to an incident beam of light; and

a plurality of energy sensitive flexible cantilever beams, each one of the plurality of flexible cantilever beams being affixed to a corresponding one of said plurality of reflective surfaces, wherein a selected energy sensitive flexible cantilever beam is constructed and arranged to move at least one of said reflective surfaces into a second position intersecting said incident beam of light when connected to an energy source, whereby when said at least one reflective surface is in said second position the at least one incident beam of light is reflected to at least one receptor by the at least one reflective surface which is caused to move from said first position to said second position by the selected energy sensitive flexible cantilever beam.

26. The thermally operated optical switch as defined in Claim 25 wherein said energy sensitive flexible cantilever beams include a dielectric structural layer either attached to one, or sandwiched between two conducting layers.

27. The thermally operated optical switch as defined in Claim 25 wherein said dielectric structural layer is made from a material selected from a group including single or polycrystalline silicon, silicon dioxide, and silicon nitride.

28. The thermally operated switch as defined in Claim 25, wherein said energy sensitive flexible cantilever beam includes a pair of substantially parallel dielectric structural layers separated by an air layer, each of said substantially parallel dielectric structural layers including a conducting layer.

29. The thermally operated switch as defined in Claim 25, wherein said energy sensitive flexible cantilever beam includes a two substantially parallel cantilevered mounted arms, each of said two substantially parallel cantilever mounted arms characterized by having a different current density when connected to a source of electrical energy.

30. The thermally operated switch as defined in Claim 25 wherein said reflective surfaces are placed at substantially 45° to said incident beam of light.

ABSTRACT OF THE INVENTION
THERMALLY ACTUATED OPTICAL SWITCH

A thermally actuated spectroscopic optical switch including reflective surfaces which are selectively moved into a position intersecting a beam of light by applying electrical or heat energy to a selected composite cantilever beam on which the reflective surface is mounted.

FIG. 1

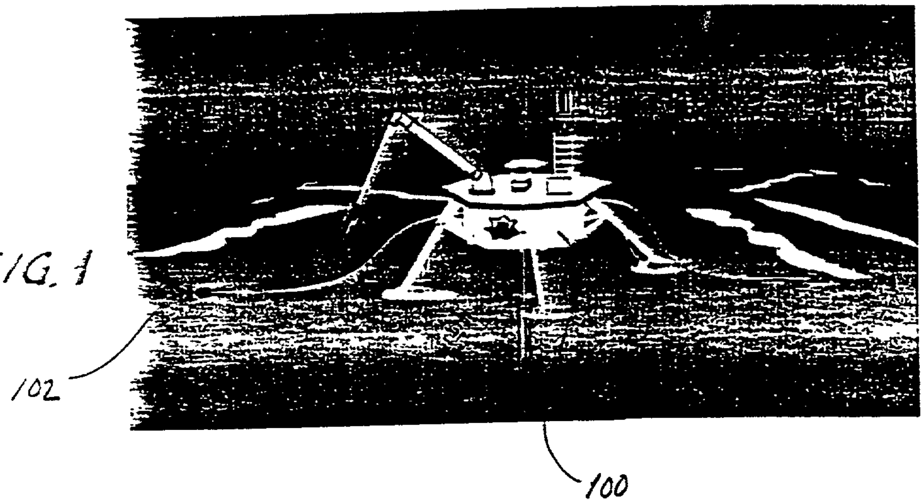


FIG. 2A

FIG. 2B

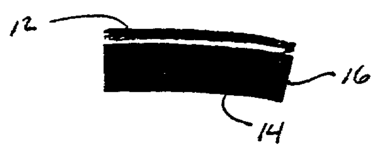


FIG. 3

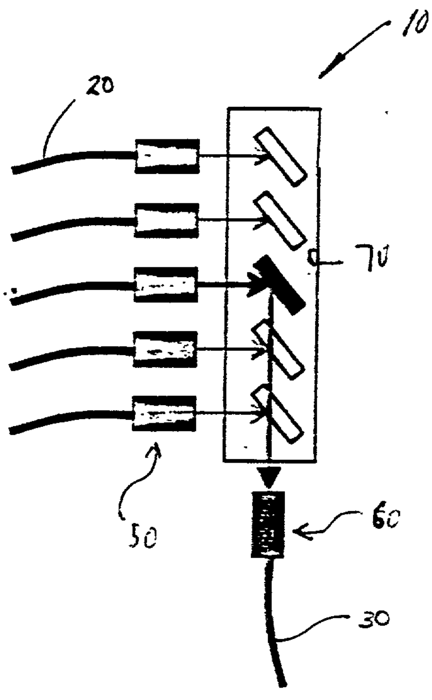


FIG. 4A

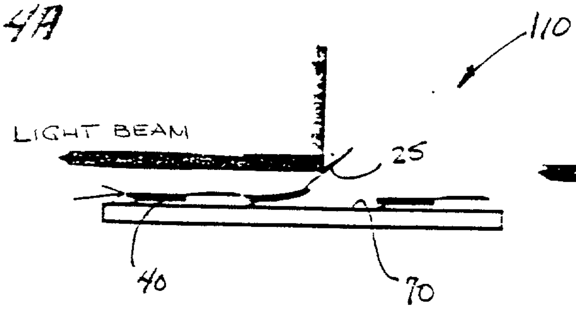


FIG. 4B

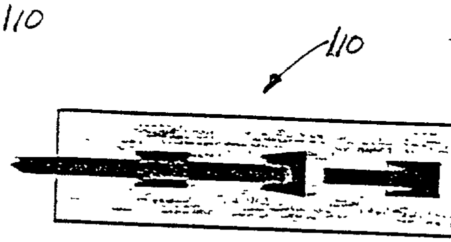


FIG. 5A

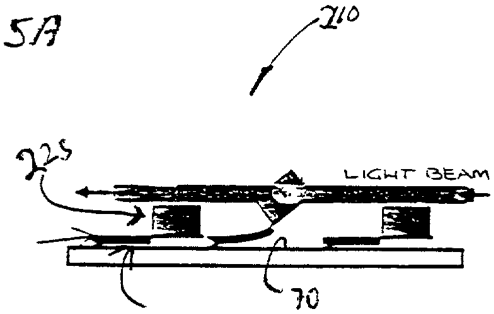
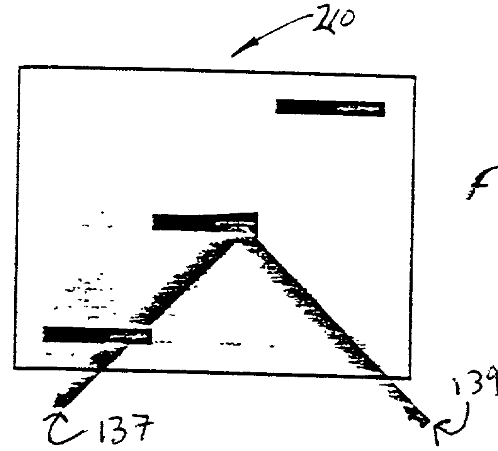


FIG. 5B



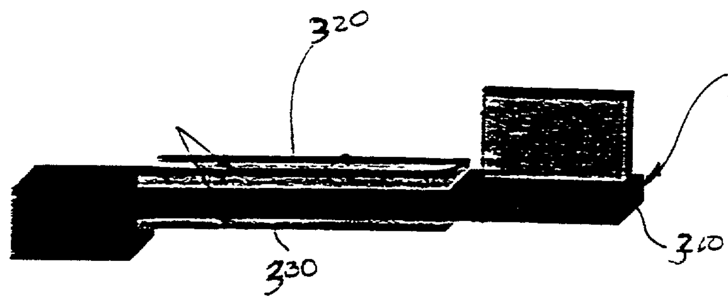


FIG. 6A

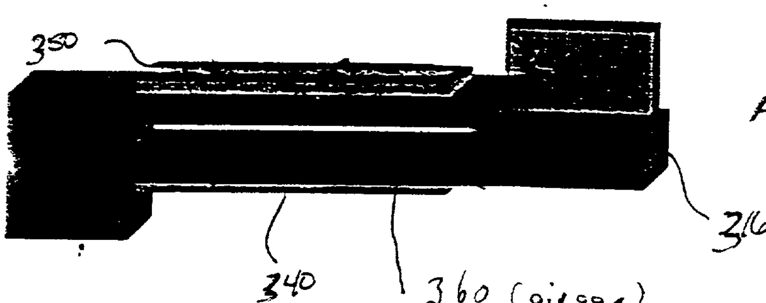


FIG. 6B

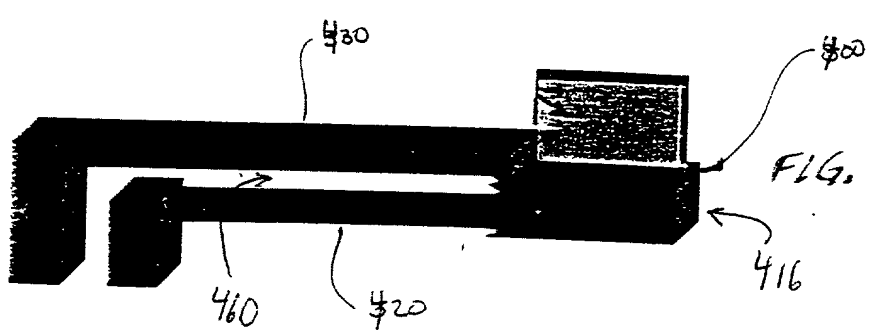


FIG. 7

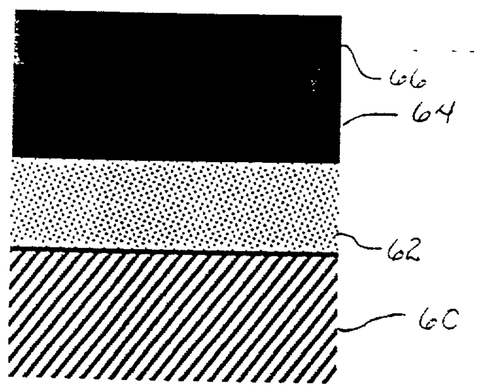


FIG. 8

PATENT APPLICATION
DOCKET NO.: 26552-00172

RULES 63 AND 67 (37 C.F.R. 1.63 and 1.67)
DECLARATION AND POWER OF ATTORNEY

FOR UTILITY/DESIGN/CIP/PCT NATIONAL APPLICATIONS

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; and

I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **THERMALLY ACTUATED SPECTROSCOPIC OPTICAL SWITCH**, the specification of which: (mark only one)

X (a) is attached hereto.
__ (b) was filed on __________ as Application Serial No. ________ and was amended on _____ (if applicable)
__ (c) was filed as PCT International Application No. PCT/_____ on ____ and was amended on _____ (if applicable).
__ (d) was filed on ___ as Application Serial No. ___ and was issued a Notice of Allowance on ____.
__ (e) was filed on ___ and bearing attorney docket number ____

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above or as allowed as indicated above.

I acknowledge the duty to disclose all information known to me to be material to the patentability of this application as defined in 37 CFR § 1.56. If this is a continuation-in-part (CIP) application, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose to the Office all information known to me to be material to patentability of the application as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

I hereby claim foreign priority benefits under 35 U.S.C. § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate filed by me or my assignee disclosing the subject matter claimed in this application and having a filing date (1) before that of the application on which my priority is claimed or, (2) if no priority is claimed, before the filing date of this application:

PRIOR FOREIGN PATENTS

Number	Country	Month/Day/Year Filed	Date first laid-open or Published	Date patented or Granted	Priority Claimed Yes	No

I hereby claim the benefit under 35 U.S.C. § 120/365 of any United States application(s) listed below and PCT international applications listed above or below:

PRIOR U.S. OR PCT APPLICATIONS

Application No. (series code/serial no.)	Month/Day/Year Filed	Status(pending, abandoned, patented)

NONE

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all of the firm of **JENKENS & GILCHRIST, a Professional Corporation**, 1445 Ross Avenue, Suite 3200, Dallas, Texas 75202-2799, as my attorneys and/or agents, with full power of substitution and revocation, to prosecute this application, provisionals thereof, continuations, continuations-in-part, divisionals, appeals, reissues, substitutions, and extensions thereof and to transact all business in the United States Patent and Trademark Office connected therewith, to appoint any individuals under an associate power of attorney and to file and prosecute any international patent application filed thereon before any international authorities, and I hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/organization who/which first sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct them in writing to the contrary.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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